



## Experimental bifurcation by using control-based continuation

Bureau, Emil; Santos, Ilmar; Thomsen, Jon Juel; Starke, Jens; Schilder, Frank; Elmegård, Michael

*Publication date:*  
2011

*Document Version*  
Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

*Citation (APA):*  
Bureau, E. (Author), Santos, I. (Author), Thomsen, J. J. (Author), Starke, J. (Author), Schilder, F. (Author), & Elmegård, M. (Author). (2011). Experimental bifurcation by using control-based continuation. Sound/Visual production (digital)

---

### General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

# Experimental bifurcation analysis by using control-based continuation

DCAMM 13th internal Symposium 2011

Emil Bureau, Ph.d. student at DTU/MEK\*

Ilmar F. Santos (MEK), Jon J. Thomsen (MEK), Jens Starke (MAT), Frank Schilder (MAT) & Michael Elmegård

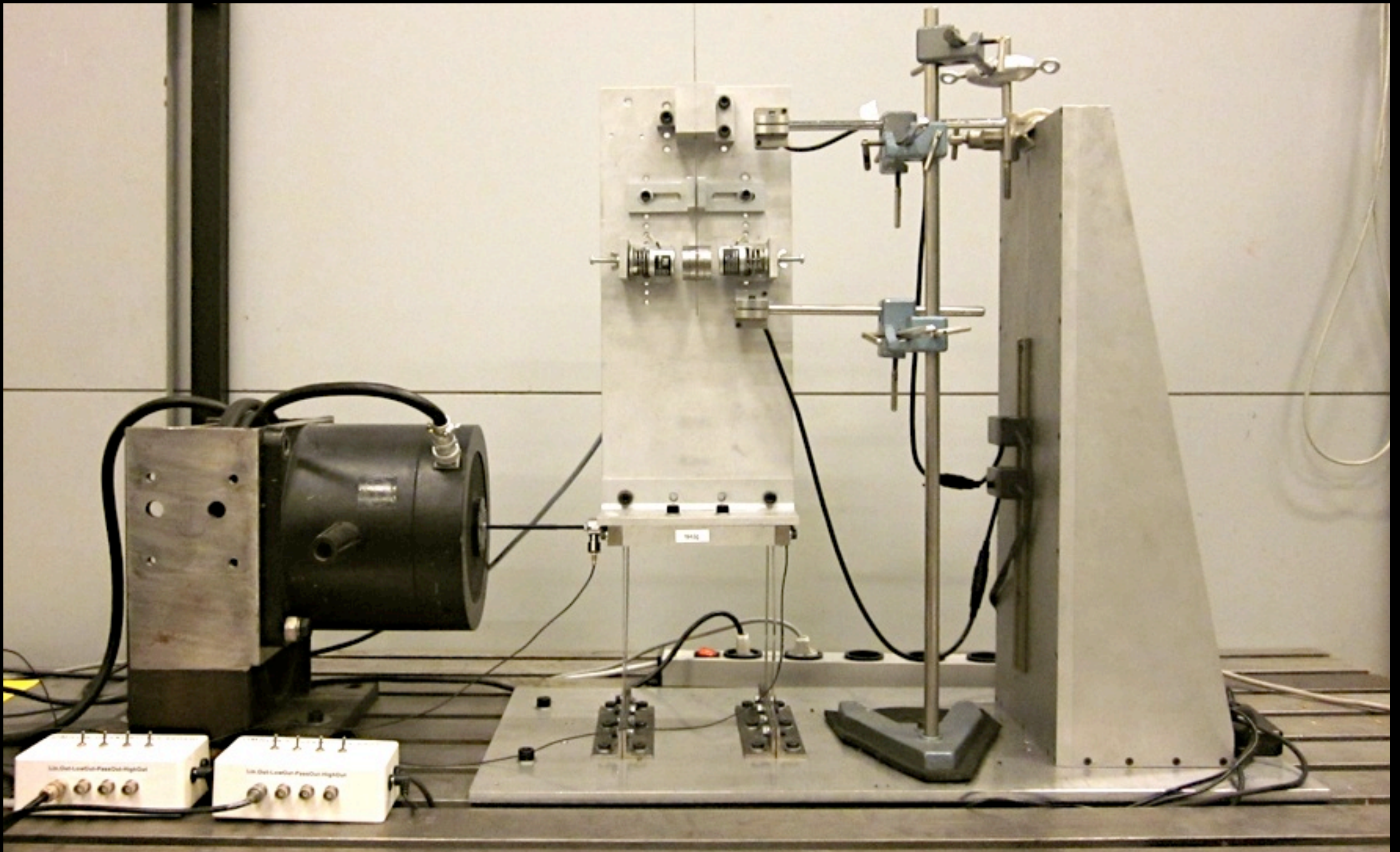
\*) Project is funded by The Danish Agency for Science, Technology and Innovation.

# Method

---

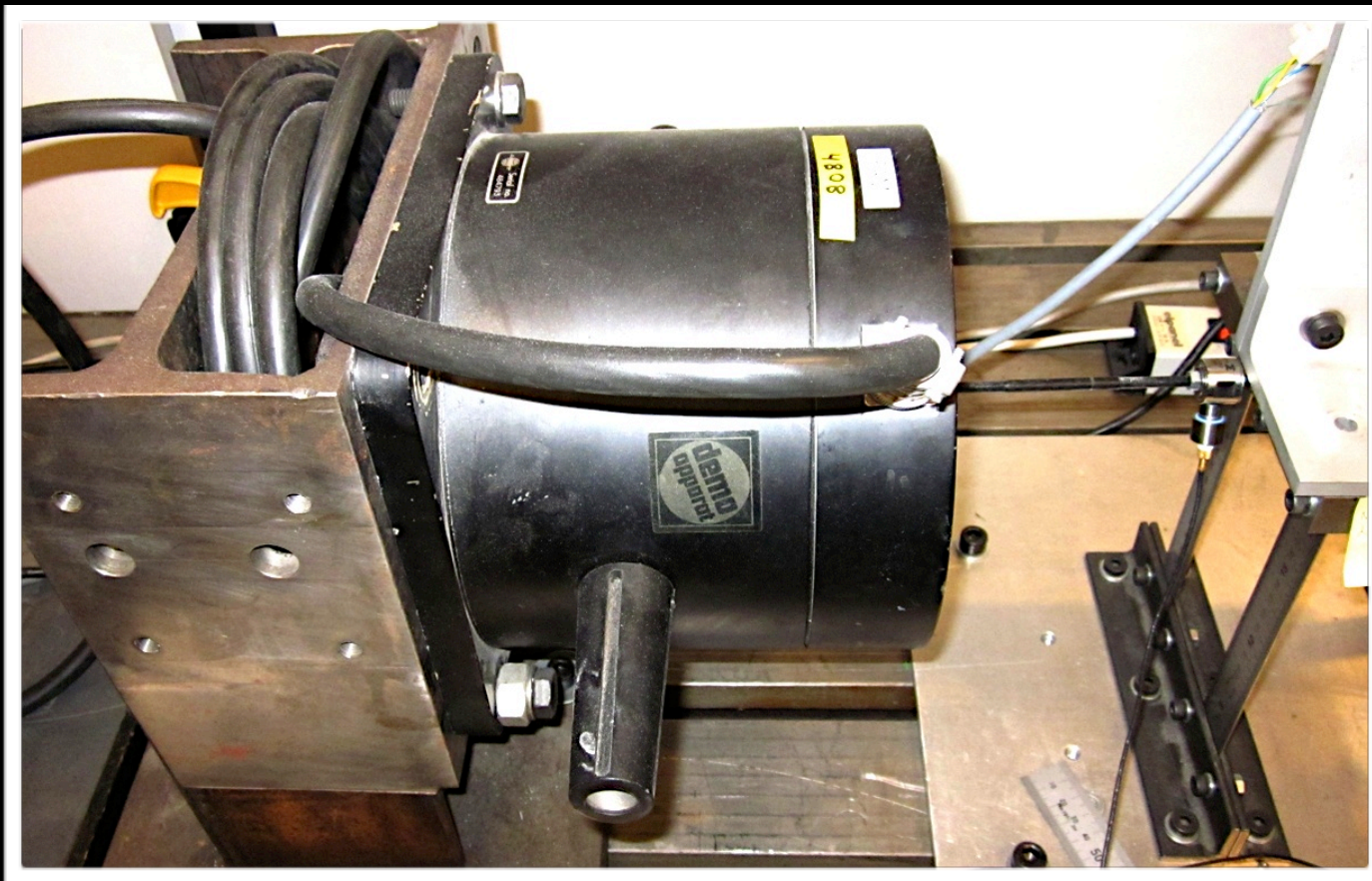
- Systematically explore non-linear dependency on parameters directly on the physical system.
- Non-invasive control.
- Track unstable vibrations.
- Applications for control-based continuation.

# Experimental setup

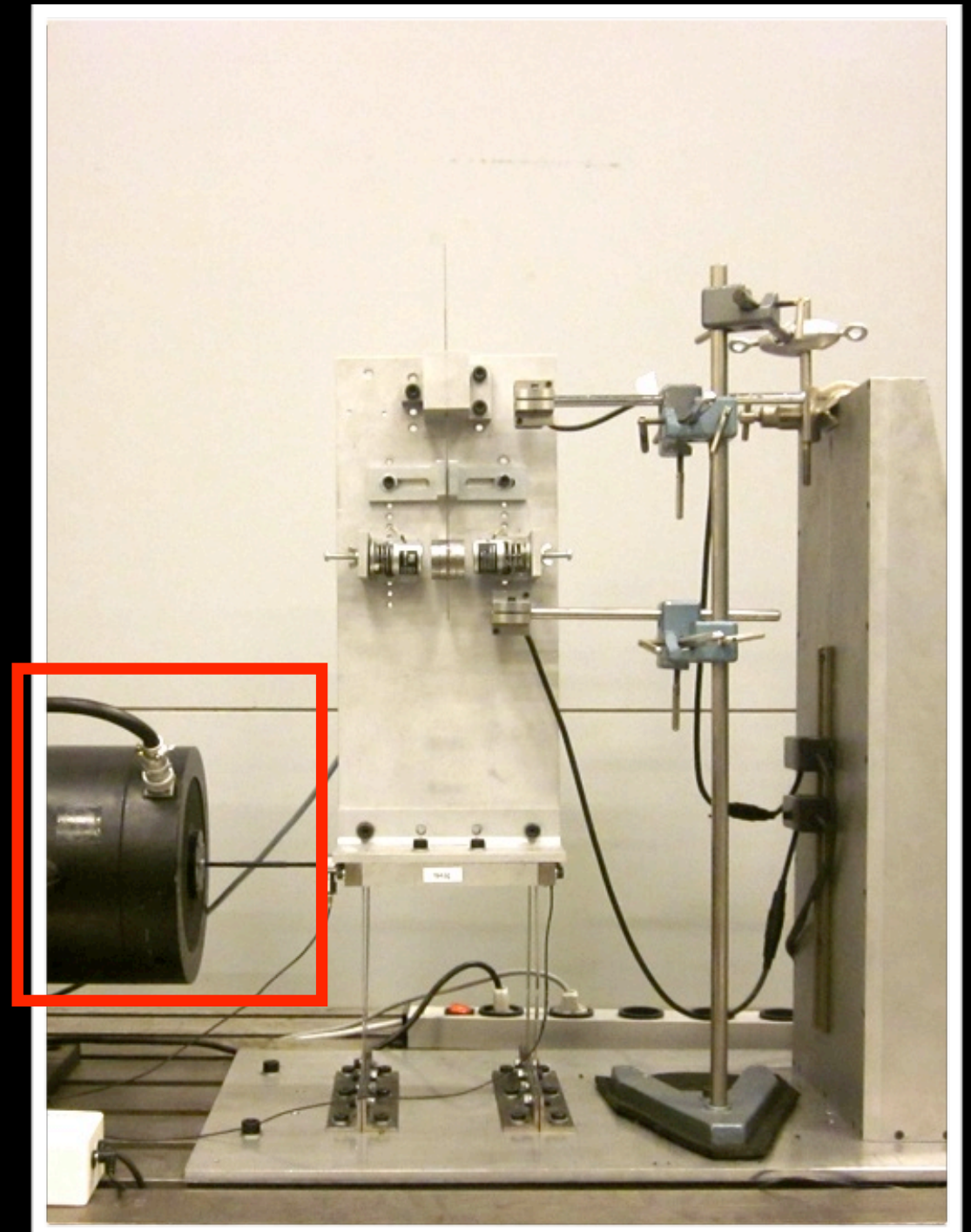




# Experimental setup



*Electromagnetic shaker*





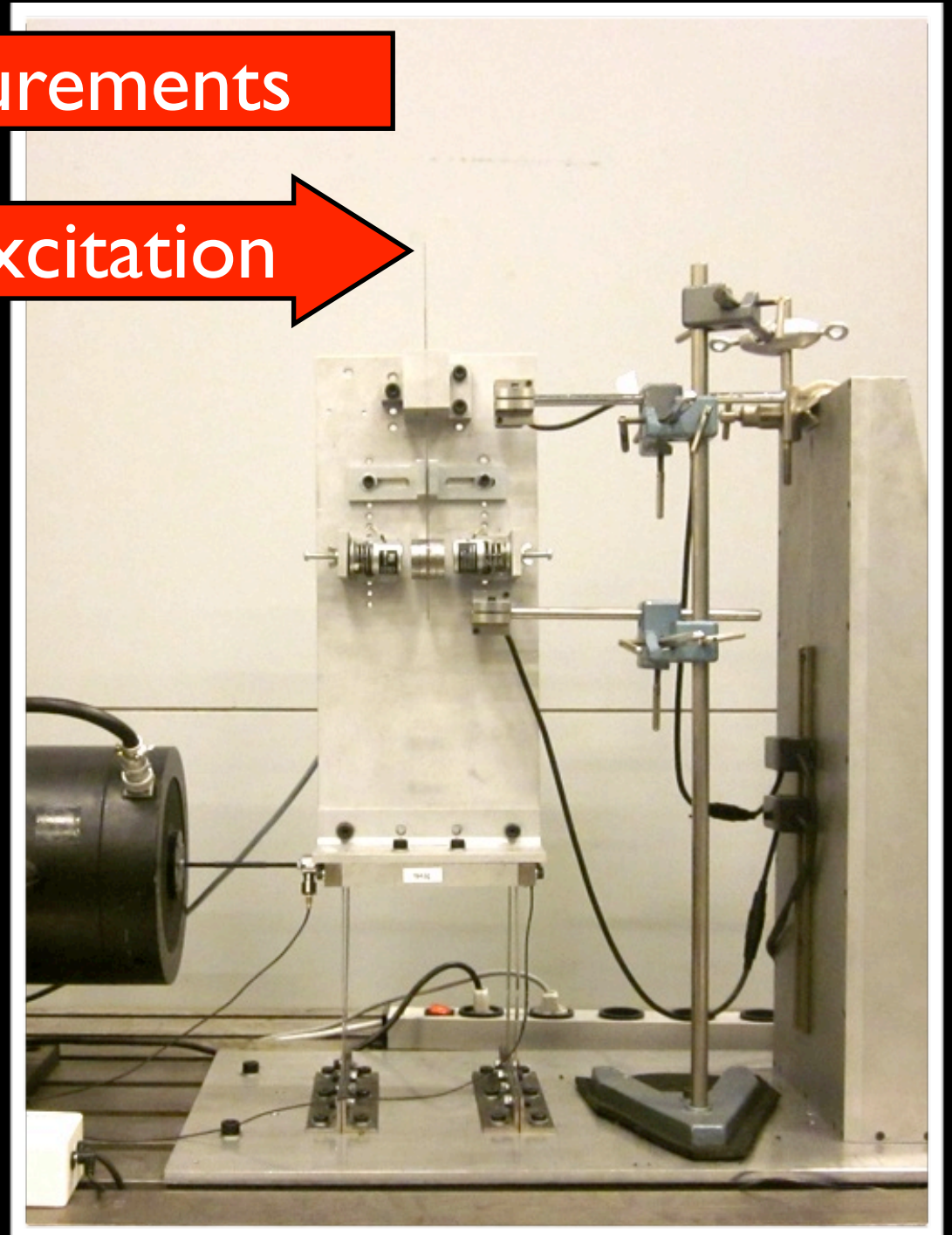
# Experimental setup



*dSpace DS1104 controller board*

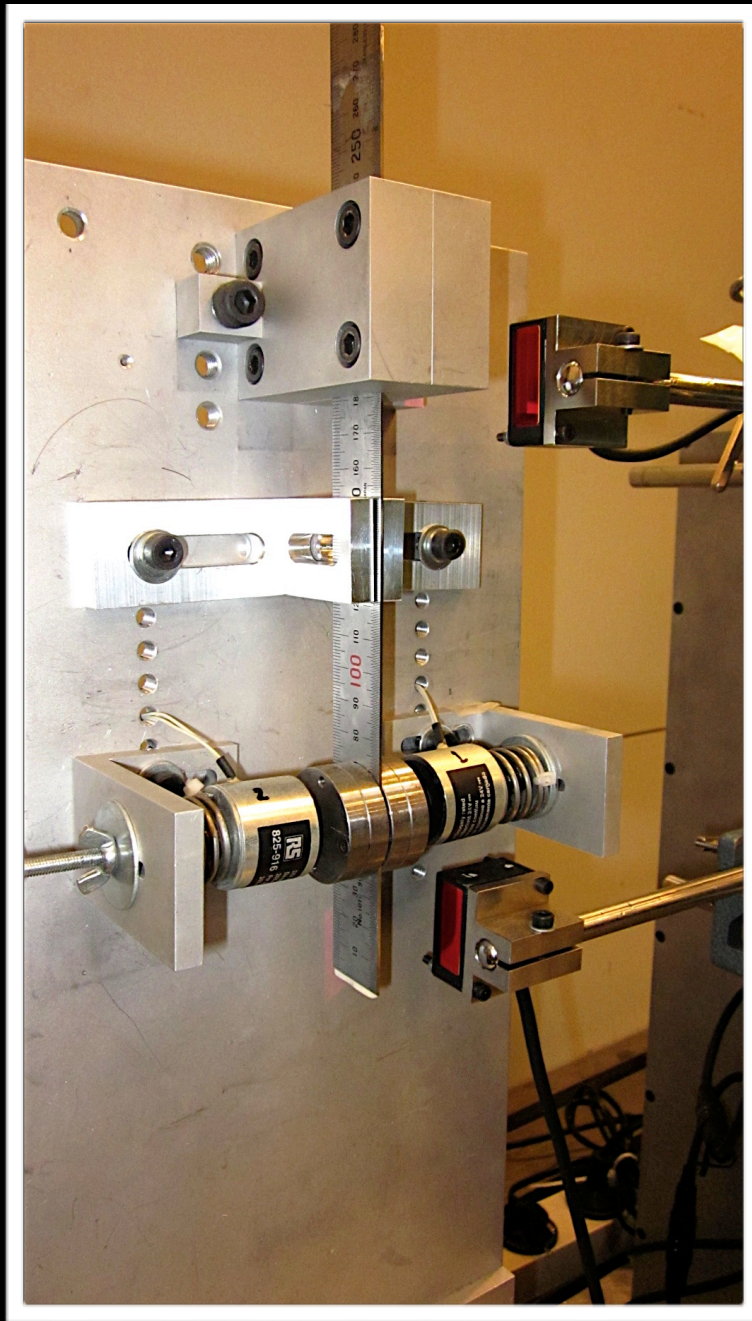
Measurements

Control & Excitation

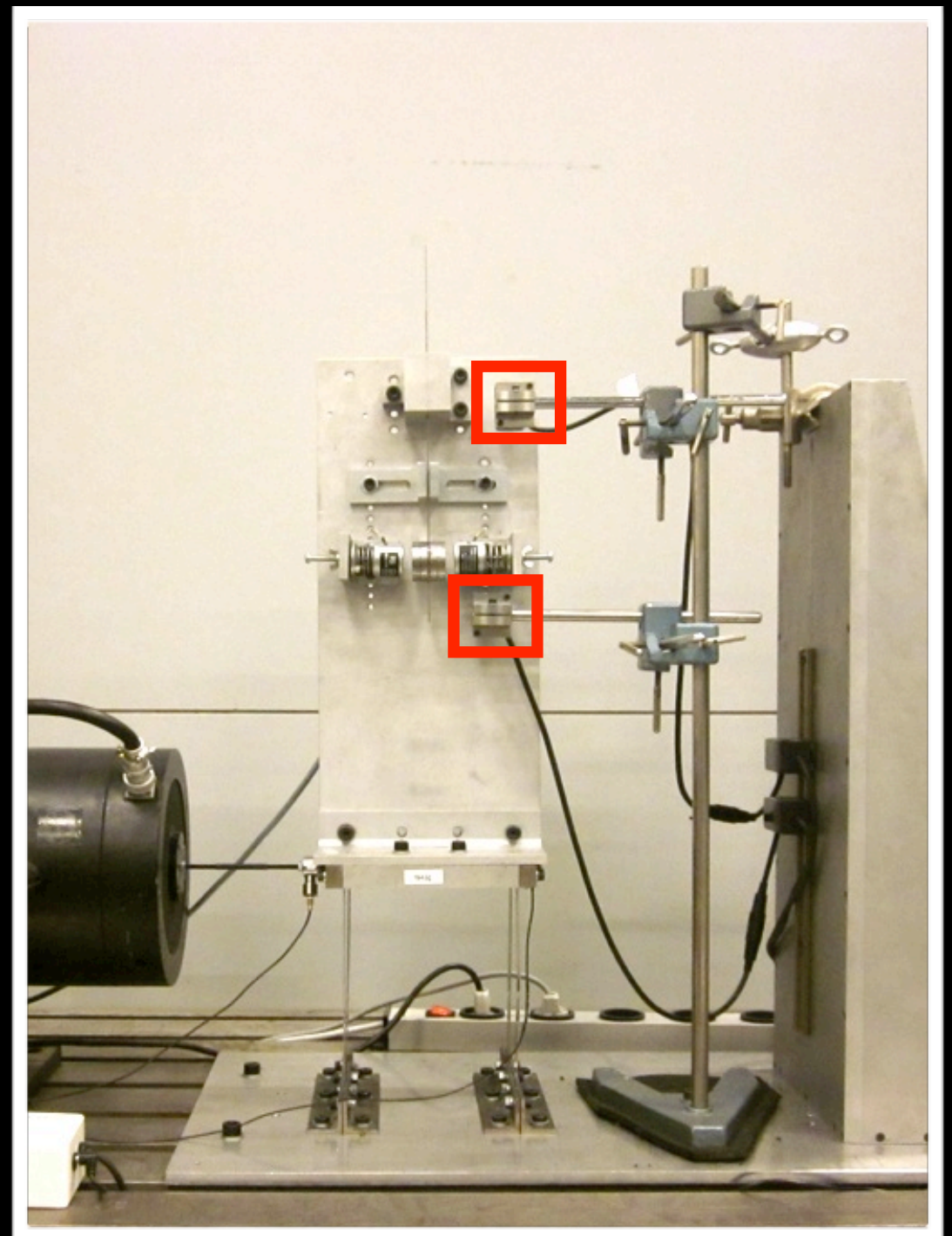




# Experimental setup



*Laser displacement sensors*

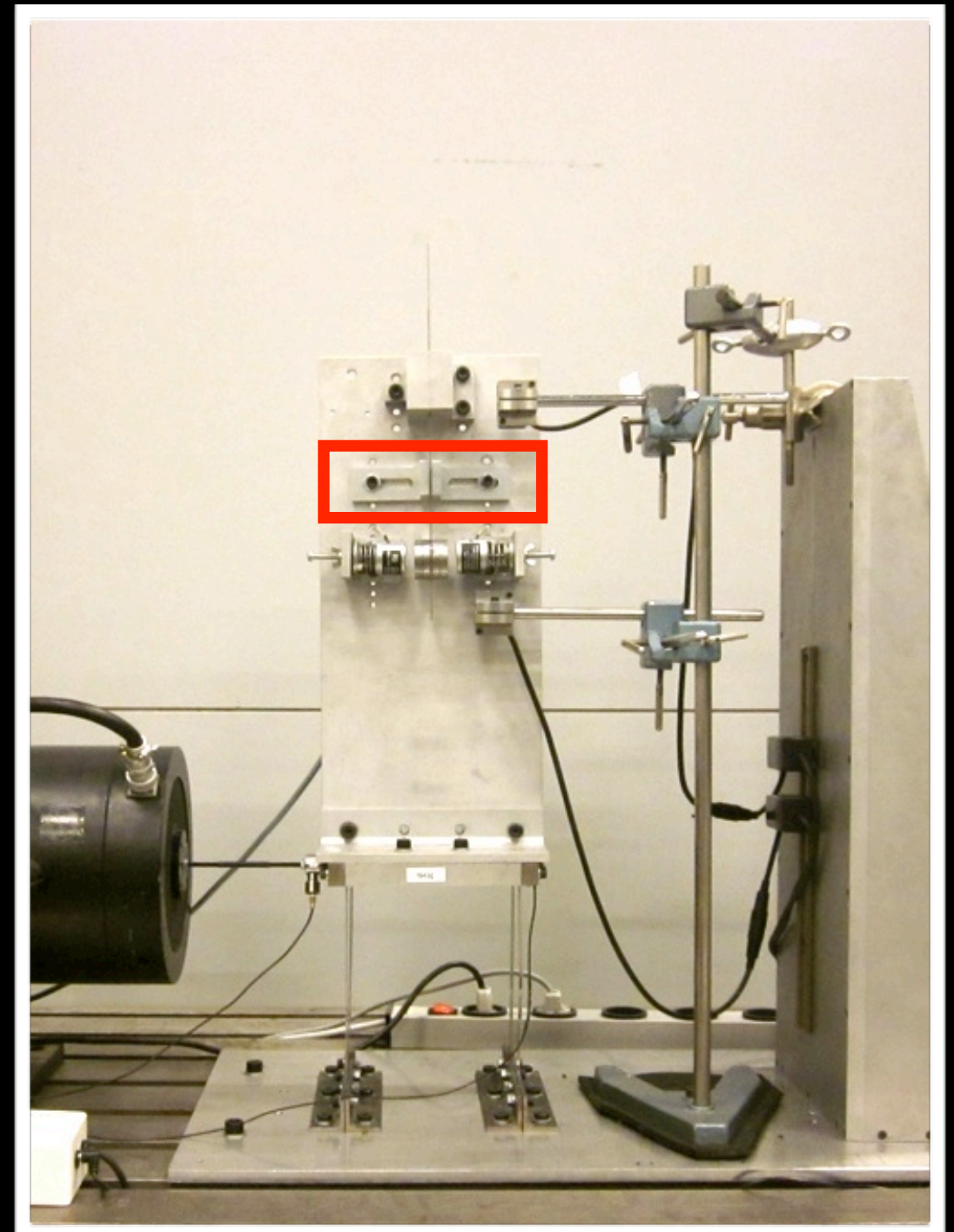




# Experimental setup

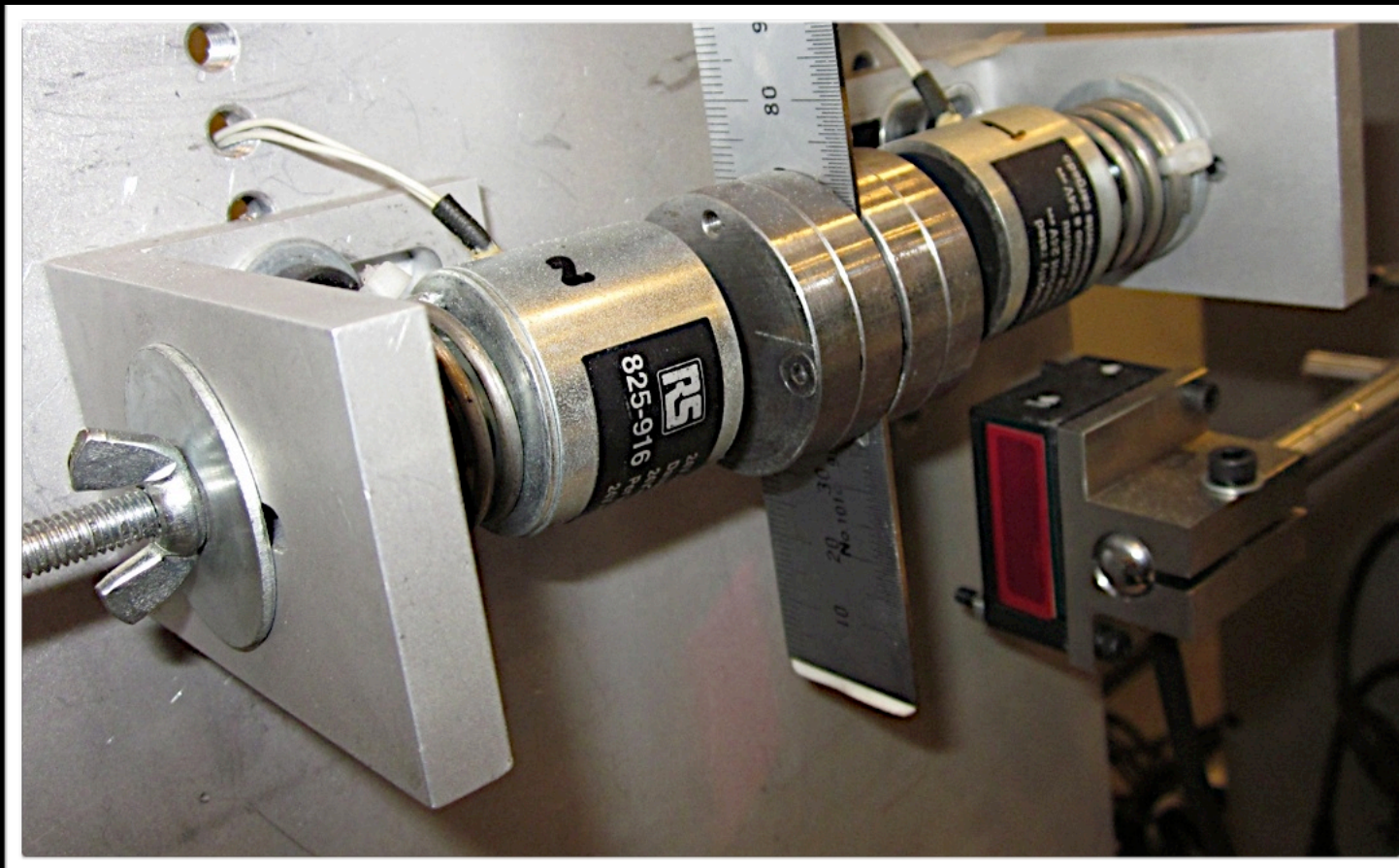


*Adjustable mechanical stops*

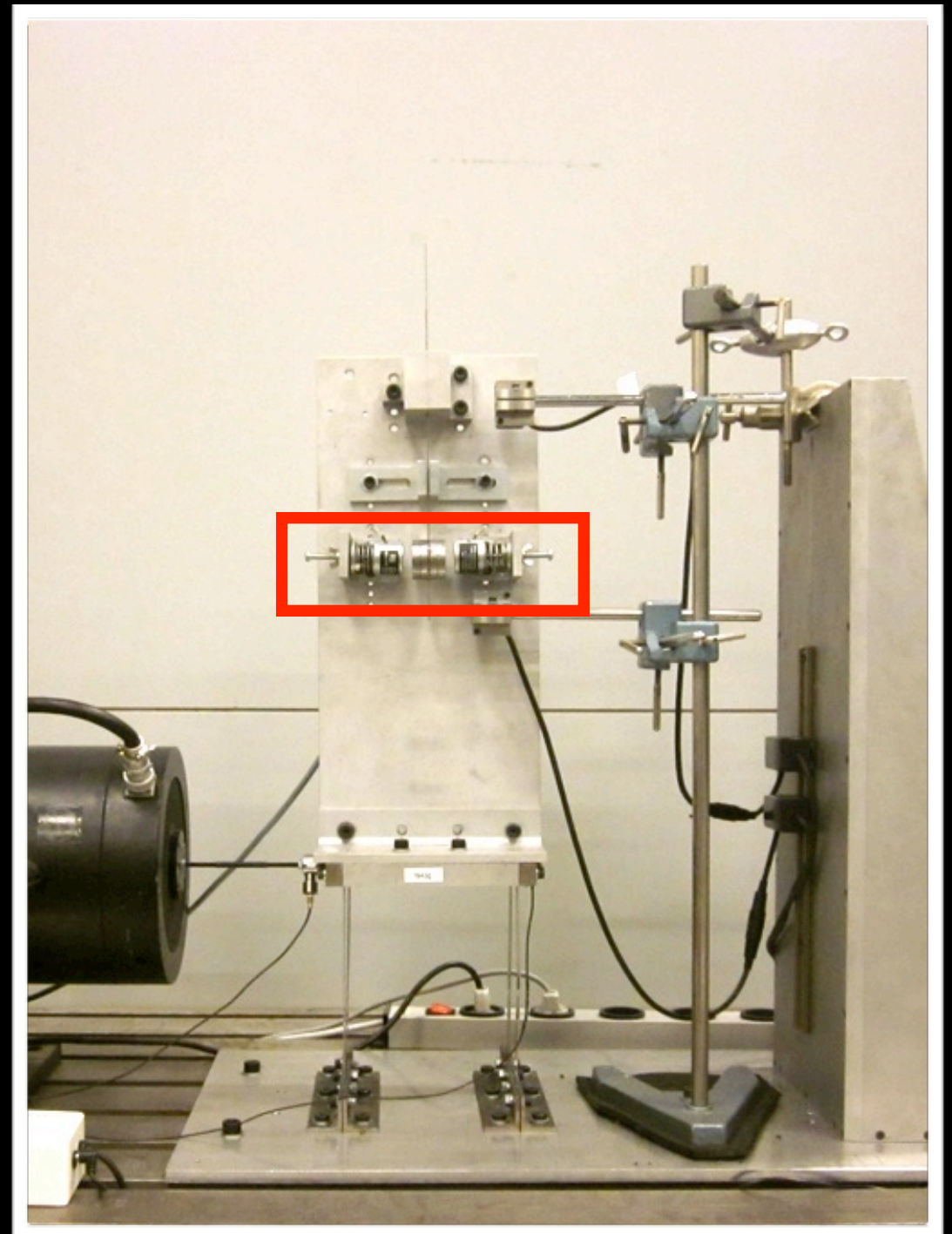




# Experimental setup



*Electromagnetic actuators*



# Experimental setup

## REAL TIME APPLICATION

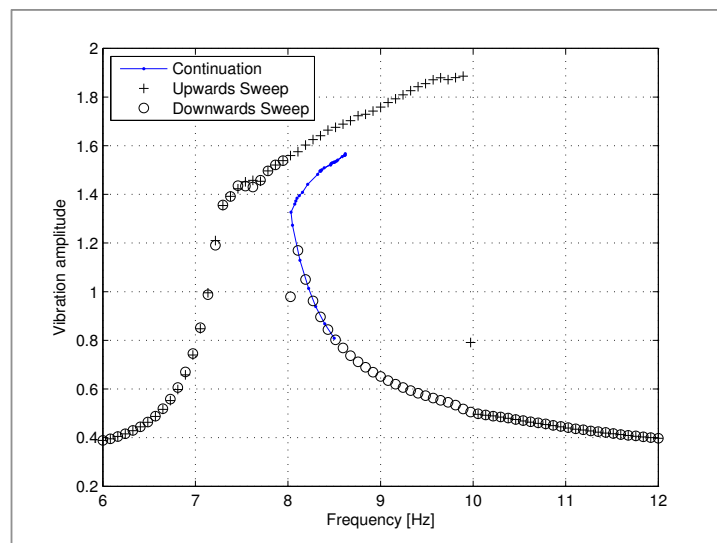
**dSPACE**



*DS1104 Controller board running the compiled Matlab/Simulink model*

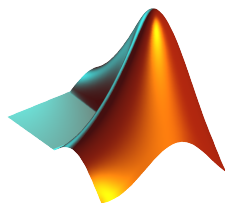
- PD-Control
- Signal for vibration-shaker
- Signal filtering
- Fourier Transformation

## BIFURCATION DIAGRAM



Accepted steps  
are plotted

## ASYNCRONOUS OFFLINE TASK



*PC Running Matlab and dSpace Controldesk*

- Experiment monitoring
- Coco (Continuation Core) & Toolbox

Control Target  
provided by Coco  
(Fourier projection)

PD-Control gains

Shaker excitation  
parameters

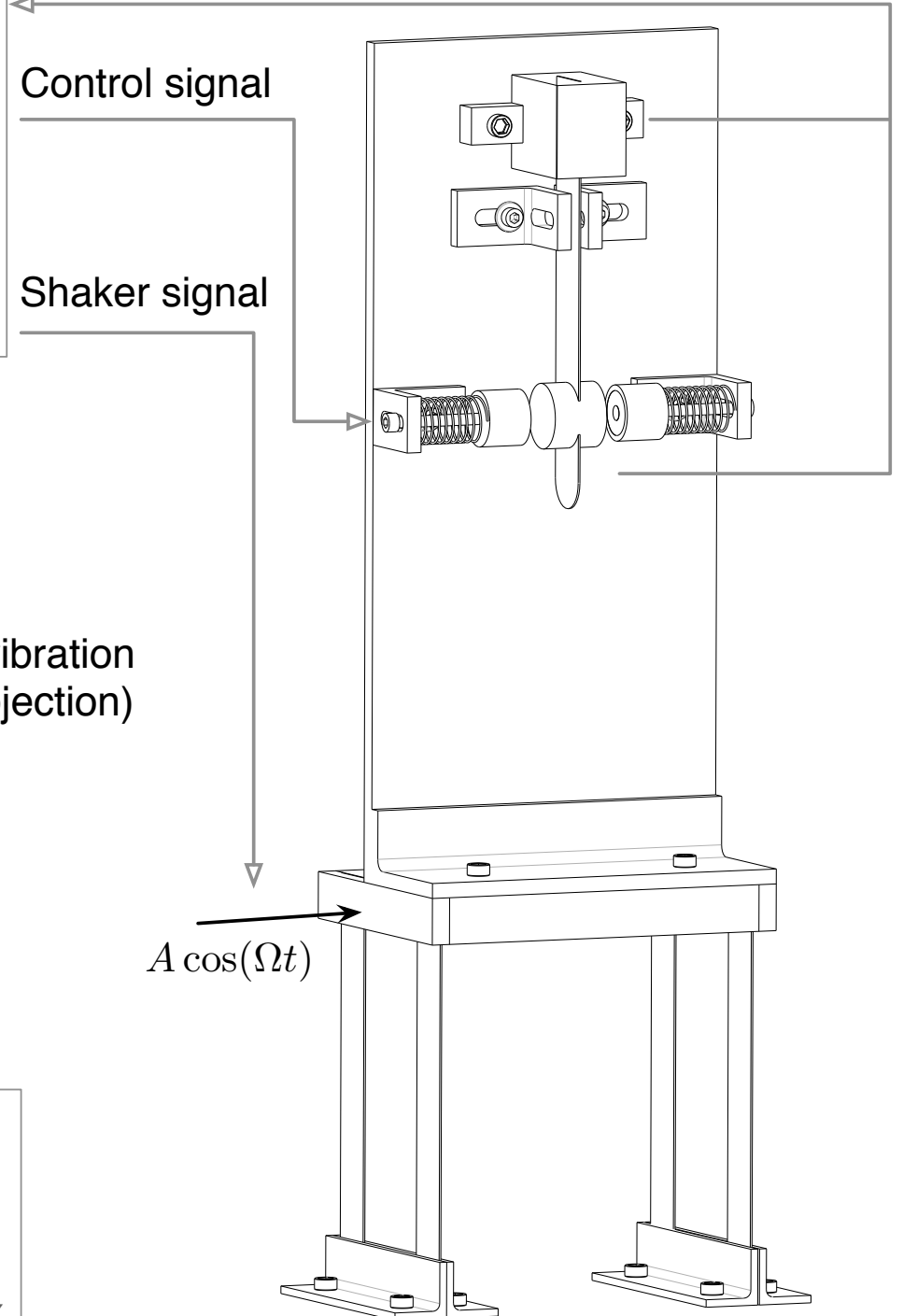
Measured vibration  
(Fourier projection)

Measured relative displacement in time

Control signal

Shaker signal

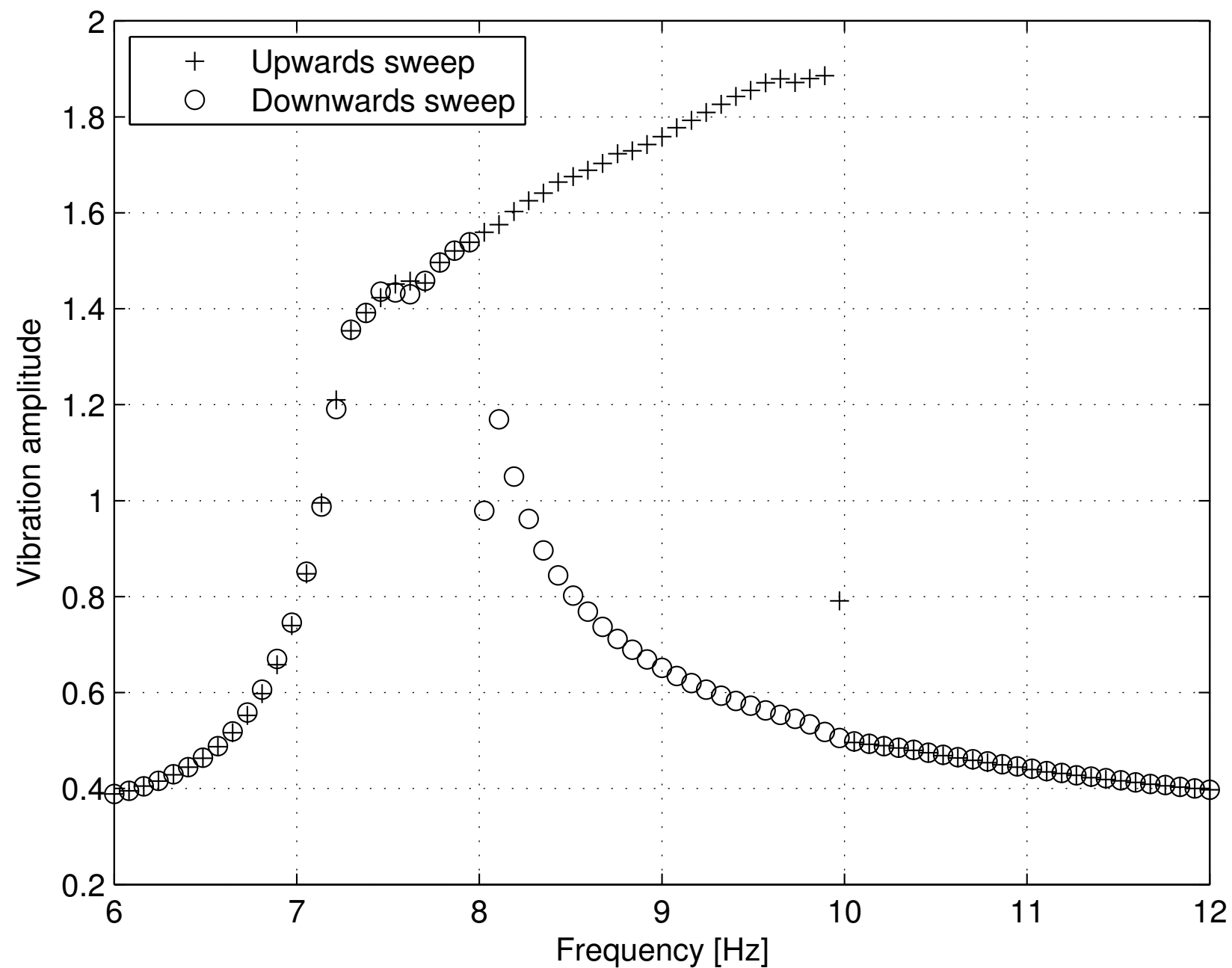
$A \cos(\Omega t)$





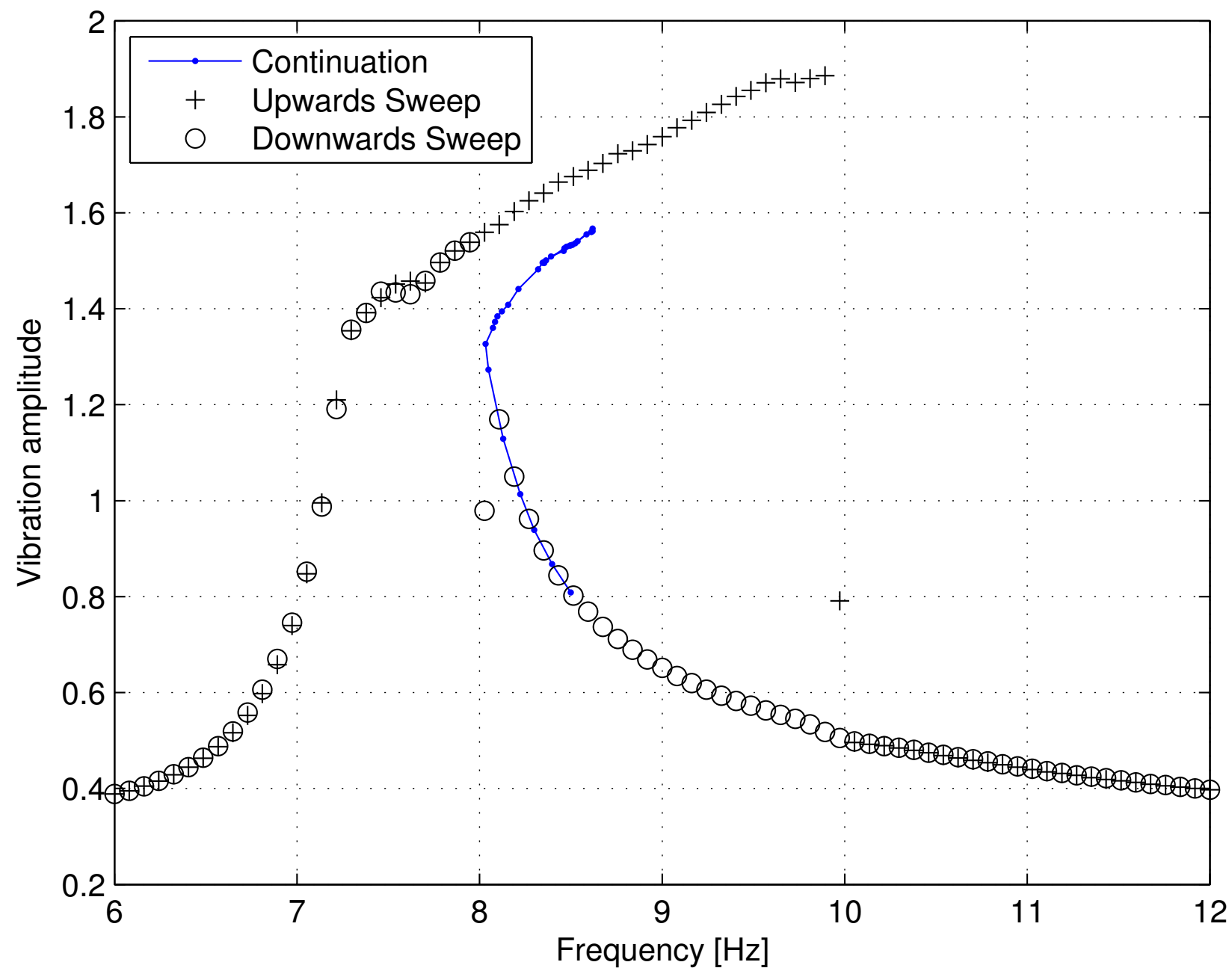
# Results

## Bifurcation diagram found by frequency sweep



# Results

Bifurcation diagram found by control-based continuation





# Perspectives

---

- Extension of the pendulum test rig and toolbox development.
- Rotor dynamics - intelligent machine elements.
- Example: Investigation of bearing properties for foil-bearings.
- Method is applicable in many areas. If the system has a closed control loop, the necessary hardware is already present.

**Thank you for your attention!**